



56, 118/c

WHITEHURST, J.


An attempt toward obtaining invariable measures. [Followed by] Appendix

[And] Three papers... from the Phil. Trans.

Part of his collected works, 1792 or 1812

Mis-bound with 'Three papers' at front.

Observations on the ventilation of rooms. 1794



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Should follow
An attempt ...

THREE PAPERS,
ON DIFFERENT SUBJECTS,
FROM THE
PHILOSOPHICAL TRANSACTIONS.



PAPERS FROM THE PHILOSOPHICAL TRANSACTIONS.

I. *Thermometrical Observations at Derby, by Mr. John Whitehurst, communicated by Charles Morton, M. D. Sec. R. S.*

[From vol. 57, page 265. Received April 9, 1767, and read May 14, 1767.]

DEAR SIR,

WE experienced a much greater degree of cold at Derby, in the late frost, than perhaps was ever observed in England; and the quick transitions were no less remarkable.

On Sunday the 18th of last month, at nine of the clock in the evening, my thermometer stood at 20. At half an hour after nine, nearly one degree below 0. At seven the next morning, 30, external air.

I am, Sir,

Derby,
Feb. 15, 1767.

Your most obedient Servant,

JOHN WHITEHURST.

II. *Account of a Machine for raising Water, executed at Oulton, in Cheshire, in 1772. In a Letter from Mr. John Whitehurst to Dr. Franklin.*

[From vol. 65, page 277; read March 16, 1775.]

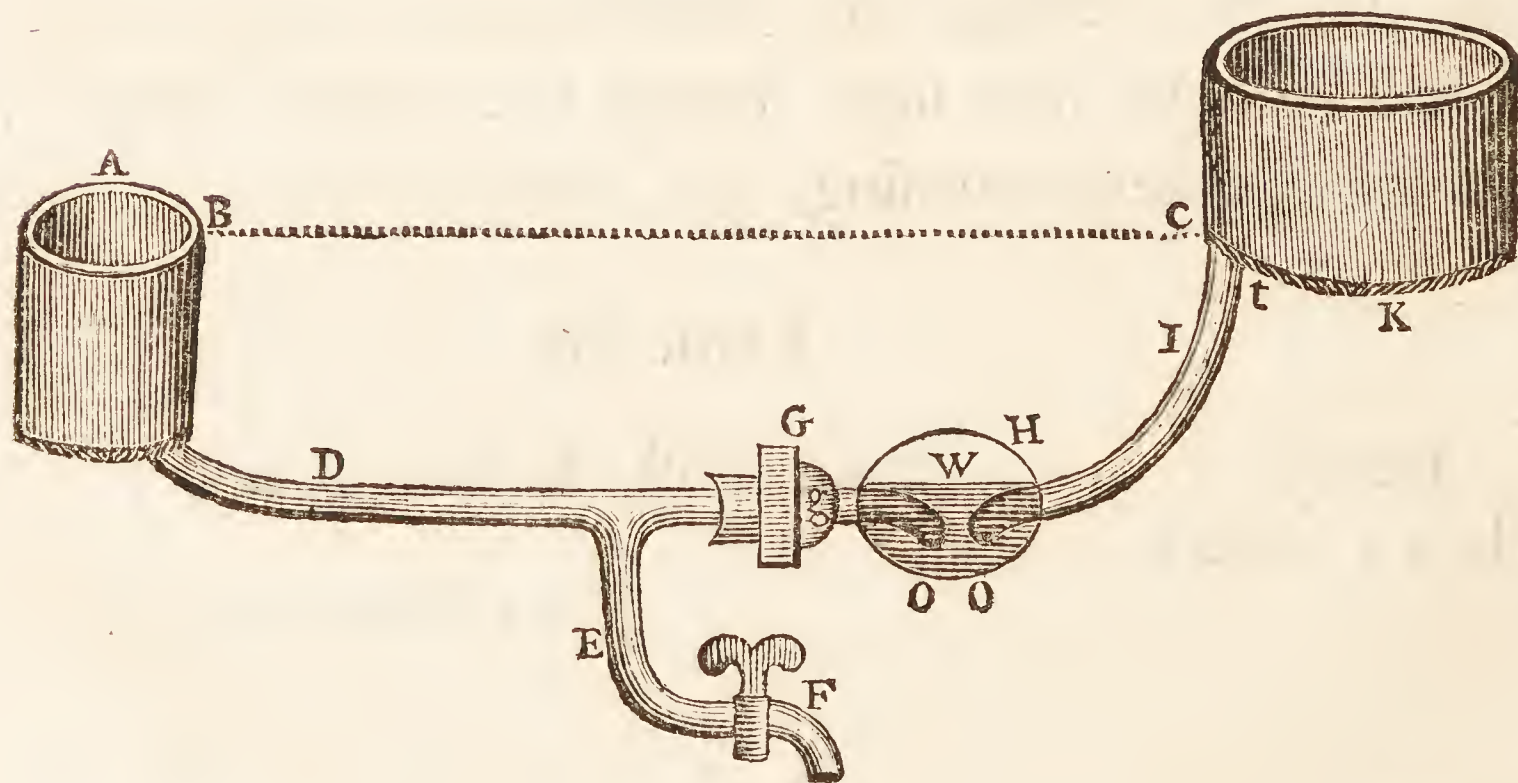
DEAR SIR,

PRESUMING the mode of raising water by its momentum may be new and useful to many individuals, induces me to send you the inclosed plan and description of a work, executed in the year 1772, at Oulton, in Cheshire, the seat of Philip Egerton, esq. for the service of a brewhouse and other offices, and is found to answer effectually.

I am, Sir,

Your most obedient Servant,

JOHN WHITEHURST.



Please

Please to observe, that the circumstances attending this waterwork, require a particular attention, and are as follows; A represents the spring or original reservoir, whose upper surface coincided with the horizontal line B C, and the bottom of the reservoir K. D the main pipe, one inch and a half diameter, and nearly 200 yards in length. E a branch pipe, of the former dimensions, for the service of the kitchen offices. Now it is to be observed that the kitchen offices are situated at least 18 or 20 feet below the surface of the reservoir A, and that the cock F is about 16 feet below it. G represents a valve-box, g the valve, H an air-vessel, o o the ends of the main pipe inserted into H, and bending downward, to prevent the air from being driven out when the water is forced into it, W the surface of the water. Now it is well known, that water discharged from an aperture, under a pressure of 16 feet perpendicular height, moves at the rate of 32 feet in a second of time; therefore such will be the velocity of the water from the cock F. And although the aperture of the cock F is not equal to the diameter of the pipe D, yet the velocity of the water contained in it will be very considerable: consequently, when a column of water, 200 yards in length, is thus put into motion, and suddenly stopped by the cock F, its momentous force

will open the valve *g*, and condense the air in *H*, as often as water is drawn from *F*. In what degree the air is thus condensed, is needless to say in the instance before us; therefore I shall only observe, that it was sufficiently condensed to force out the water into the reservoir *K*, and even to burst the vessel *H*, in a few months after it was first constructed, though apparently very firm, being made of sheet lead, about nine or ten pounds weight to a square foot. From whence it seems reasonable to infer, that the momentous force is much superior to the simple pressure of the column *I K*; and therefore equal to a greater resistance (if required) than a pressure of four or five feet, perpendicular height. It seems necessary further to observe, that the consumption of water in the kitchen offices is very considerable; that is, that water is frequently drawing from morning till night all the days of the year.

III. *Expe-*

III. *Experiments on Ignited Substances.* By Mr. John Whitehurst, in a Letter to James Stuart, Esquire, F. R. S.

[From vol. 66, page 575; read May 25, 1776.]

SIR,

London, Nov. 29, 1775.

THE experiments of Mr. Buffon upon ignited bodies seem to prove, that, when heated to the degree he mentions, they are more ponderous than when cold. The experiments which I have made on heated metals, suggest a different idea, and contradict the fact he relates; so that I am induced to believe, that some circumstance, not attended to, has introduced a mistake in the relation this learned philosopher has published as the result of his inquiry.

His experiment stands thus recorded (Suppl. Nat. Hist. vol. 2, page 11): a mass of iron, after receiving a white heat, weighed 49 pounds 9 ounces; when restored again to the temperature of the atmosphere 49 pounds 7 ounces. Hence he concluded, that the igneous particles, contained in the heated iron, increased its absolute weight 2 ounces.

My

My experiments are as follows: 1st, one pennyweight of gold, made red-hot, became apparently lighter; but, when restored again to the temperature of the atmosphere, its former weight was perfectly restored.

2d, One pennyweight of iron, heated as above, was also apparently lighter; but, when it became cool again, its weight was visibly augmented.

It is now several years since I made these experiments; but I well remember to have repeated them several times, and that the results were always the same. It may be necessary to remark, that the beam used in these experiments, was sensibly affected by the 2000th part of a grain; and likewise, that each of the metals was heated upon charcoal, by means of a candle and a blow-pipe, and both were brought nearly to a state of fusion.

It seems needless to observe, that the apparent levity of the gold and of the iron, when hot, was owing to the ascent of the rarefied air above the scale, and to the tendency of that underneath to restore the equilibrium of its pressure. The increase of weight in the iron might probably arise from its having, in some degree, acquired the property of steel, by means of the flame and charcoal.

I am

I am at a loss to account for the fallacy which seems to have attended M. Buffon's experiment ; but it seems probable, that the heat of the mass of iron employed by him, had a greater effect on that arm of the beam from which it hung than on the other, which being less heated, would consequently be less expanded ; and this difference of expansion might produce the error in M. Buffon's account of the weight of heated iron.

If these observations afford you any satisfaction, it will give me pleasure.

I am, &c.

THE END.

1. The first part of the text discusses the importance of maintaining accurate records of all transactions, including sales, purchases, and expenses. It emphasizes that proper record-keeping is essential for determining the correct amount of tax liability.

WHITEHURST, J.

AN
A T T E M P T
TOWARD OBTAINING
INVARIABLE MEASURES
OF
LENGTH, CAPACITY, AND WEIGHT,
FROM THE
MENSURATION OF TIME,
INDEPENDENT OF THE
MECHANICAL OPERATIONS
REQUISITE TO ASCERTAIN THE
CENTER OF OSCILLATION,
OR THE
TRUE LENGTH OF PENDULUMS.

I N T R O D U C T I O N.

MANY diligent and elaborate researches have been made by the learned to ascertain the origin, and proportions, of weights and measures established in various parts of the world. From these inquiries it appears, that several nations attempted to derive them from the weight and magnitude of natural bodies, or fundry parts of them, viz. the human stature, cubit, span, leg, &c.; likewise from an hen's egg, grains of wheat, barley, and other similar productions. And these attempts were probably owing to an idea of the utility that might arise from the establishment of similar *invariable* measures of length, capacity, and weight, upon a natural foundation.

But the weight or magnitude of natural bodies of the same denomination, being subject to consider-

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able

able inequalities, these seem to have frustrated the most sagacious attempts to obtain invariable measures, and to have reduced the several states and empires to the necessity of adopting arbitrary measures, according to the dictates of their own imaginations, without any foundation in the nature of things. It is therefore obvious that weights and measures, being thus derived and established, can have no more relation or agreement with each other, than the languages of the several nations by whom they were adopted; and their being divided into a diversity of smaller parts, renders them still more incoherent and embarrassing to those nations who have any intercourse in matters relative to science, or commerce. See the tables annexed.

For although their relative proportions may be truly known, whereby the quantity of space, magnitude, or weight, ascertained by the measures of one nation, may be found correspondent to a certain number of measures of another, yet it must be owned that such operations not only demand an expence of time, but are also liable to error. It is therefore evident, that the diversity of weights and measures established by different nations, is no small impediment to the progress of *science and commerce*.

Weights and measures having been thus established from time immemorial, have excited the attention of speculative minds to obviate the difficulties and embarrassments thence arising: for it appears to have been a principal desideratum in philosophical researches, to establish weights and measures upon a permanent, unalterable foundation, whence invariable standards might be obtained, to which all nations might refer, or with which they might compare their respective measures, and reduce them to one invariable, universal denomination, for the mutual convenience and benefit of all mankind: by deriving them from such principles as might enable all future generations to obtain similar measures of length, capacity, and weight, and thereby render it altogether needless to cut them on stone, or to engrave them in brass, to perpetuate their existence.

Such however, were apparently the motives which induced those profound geometricians, Sir Christopher Wren, and Mr. Huygens, to consider the subject of invariable measures, and to suggest the idea of establishing them upon the unerring laws of nature: namely, the periodical revolutions of the heavenly bodies, and the doctrine of pendulums. Considering

time as a natural measure, depending upon the equality of the earth's diurnal rotation, or the return of the same star to the same meridian, in equal periods of time, at all times of the year, and in every year to come.

They likewise considered that the lengths of pendulums are inversely as the squares of their respective vibrations in a given time; or that their vibrations in a given time are inversely as the square roots of their respective lengths.

Upon these constant, invariable laws of motion, those celebrated philosophers proposed to have established measures of length, viz. that the length of a pendulum, vibrating seconds of time, should be taken for a standard yard, measured from its point of suspension to its center of oscillation.

Such were the principles suggested by Sir Christopher Wren and Mr. Huygens, as the basis of invariable measures, obtainable in all future ages, *under similar circumstances of latitude, elevation, temperature, &c.*

But

But notwithstanding that the principles above related are universally granted, yet, it must be owned that their application would have been attended with insurmountable difficulties in the executive part; and with great inconveniency to the public; and these objections seem to have put a final period to the application of that excellent theoretical plan, for one century at least. The impediments thence arising are as follow:

First, according to the plan laid down by mechanical writers for the purpose of ascertaining the center of oscillation, or the true length of pendulums, several mensurations are requisite to be obtained with the greatest degree of precision; and these are of so difficult a nature, that few, conversant in this business, would presume to give similar results from any two operations; but would rather previously conclude, that every attempt must be attended with an accumulation of error. The operations are to the following purport:

Let a ball that is perfectly *spherical, equally dense,* and of some of the heaviest metals, be suspended by a string, the smallest, lightest, most flexible, and the
least

least liable to stretch; let the pendulum, thus constructed, be adjusted to vibrate seconds of time, or to perform 86400 vibrations in the space of twenty-four hours mean time, or in one sidereal day.

The pendulum being thus adjusted, measure the distance between the point of suspension and the center of the ball, and likewise the radius of the ball. These proportions are given, to find a third proportional: thus — as the length, or distance between the point of suspension and the center of the ball, is to the radius, so is the radius to the third proportional. The third proportional being thus found, and divided into five equal parts, two of them are required to be transferred from the center of the ball downwards, or, added to the length obtained by mensuration, give the distance between the point of suspension, and the center of oscillation, or the true length of the pendulum.

Such are the mechanical operations requisite to ascertain the length of pendulums, whatever may be the number of vibrations in a given time; therefore the difficulties attending the application of the above
plan,

plan, are obvious to artists practically conversant in dividing.

Secondly, the inconveniency arising from the application of the above plan, is equally obvious when it is considered, that the reputed length of the pendulum which vibrates seconds in the latitude of London, is 39,2 inches, and the standard yard is only 36 inches: for if the former was established as a standard yard, it would certainly occasion a great alteration in the customary measures of England, and consequently create great confusion and inconveniency to the public.

This conjecture is abundantly verified by the quantity of time elapsed since the promulgation thereof; for it does not appear that the subject of invariable measures was resumed again before the year 1771, when that learned philosopher, Mr. Andrew Bochém, suggested the idea of obtaining invariable measures from the laws of motion, but in a very different manner; namely, by the admeasurement of the space heavy bodies descend through in one second of time. See Act. Philos. Medic. Sec. Academ. Scient. Principal: Hefsiæ. page 5, 1771: but this excellent theory, like the former, would have been attended with too much difficulty

difficulty in the executive part, to admit of a tolerable degree of precision, when it is considered that the velocity heavy bodies have acquired at the expiration of one second of time, is nearly 3,86 inches in $\frac{1}{100}$ part of a second; therefore the quantity of space bodies move through in one second, is not easily ascertained by practice.

In the year 1774, the society instituted for the encouragement of arts, manufactures, and commerce, took the subject of invariable measures into serious consideration, at the instance of Mr. Steel, a worthy member thereof, and advertised the reward of a gold medal, or the sum of one hundred guineas to any person residing in any country whatever, who should discover and communicate to the society, on or before the third Tuesday in March, 1775, a mode whereby to obtain invariable standards for weights and measures, communicable at all times, and to all nations; but the liberal encouragement thus held out to the public, was not productive of a single attempt; therefore the same advertisement was repeated the following years, viz. 1776, 1777, and 1778. In consequence thereof, on the third Tuesday in March 1779, five plans were presented to the society; amongst which,

which number, that invented by Mr. John Hatton, Watchmaker, in London, was the most approved, though not perfected to the degree of accuracy required in the construction of invariable measures.

The superiority of Mr. Hatton's plan consisted in the application of a moveable point of suspension to one and the same pendulum, in order to produce the full and absolute effect of two pendulums, the difference of whose lengths was the intended measure. But notwithstanding the superior excellency of Mr. Hatton's idea, it must be owned that the ingenious author was not equally happy in the mode of reducing it to practice. However, as the idea was new, and apparently capable of being carried to a much greater degree of perfection, the Society, in consideration of its merit, and as some encouragement to re-consider the subject, presented him with the sum of thirty guineas; and they also renewed their former advertisement as a farther inducement to improve his plan, in hopes of obtaining the end proposed the following year, but were disappointed in their expectations; for several years elapsed, and no steps were apparently taken by Mr. Hatton towards a more effectual application of the principles he suggested; it was therefore

generally supposed the inventor of this machine had totally declined any farther consideration of the subject. These considerations, together with the favourable opinion I entertained of his scheme, induced me to attempt some improvement in the construction of Mr. Hatton's apparatus, in order to preserve his idea from being too hastily abandoned.

Having had the honour of attending at the exhibition of the several plans, at the request of the Society, and of examining amongst others the design and construction of Mr. Hatton's apparatus, I became persuaded in my own mind, that it was capable of being improved so far as to answer its purpose with a greater degree of accuracy than may be generally imagined; I was therefore induced to resume the subject of invariable measures, and to attempt the construction of an apparatus with which experiments have been making for several years past, which leave little room to doubt, but that measures of length may be obtained with precision; notwithstanding the prejudice which prevails in the minds of many eminent philosophers against the accuracy of pendulous experiments, and particularly against the application of maintaining powers, which arise from a conception that such ap-
ap-

plications must necessarily accelerate, or retard, the vibrations, and render the result fallacious. And it must be owned, that according to the general construction of clocks a century ago, they were liable to produce such effects. But it is well known by those who are conversant with the modern improvements of clockwork, that the maintaining power may be so applied as not to interfere in any sensible degree with the vibrations; and such provision is made in the construction of the apparatus as will effectually prove the truth, or fallacy, of such conjectures.

For though fundry impediments unavoidably accompany the construction of time-keepers, and interfere in some degree with the mensuration of time, so as to exclude the result of such experiments from any pretensions to mathematical exactness; yet it evidently appears, from a series of several years experiments, that measures may be obtained from the mensuration of time, sufficiently accurate for the various purposes of human life. To what degree of accuracy such machines are capable of being brought, will best appear from the experiments themselves.

A N
A T T E M P T
TOWARDS OBTAINING
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OF
LENGTH, CAPACITY, AND WEIGHT,

FROM THE
MENSURATION OF TIME,

Independent of the mechanical Operations requisite to ascertain the
Center of Oscillation, or the true Length of

P E N D U L U M S.

S E C T I O N I.

Of the general Design of the Apparatus.

P REVIOUS to a description of the apparatus adapted to the purpose of obtaining invariable measures, it may not be improper to premise the principal objects of its construction:

First,

First, it is proposed to obtain a measure of the greatest length convenience will permit, from the mensuration of time, with ease and certainty; presuming that a measure of considerable length may be subdivided with a much greater degree of accuracy, than a short one can be multiplied into a longer.

Secondly, it is proposed to obtain the measure from two pendulums, whose vibrations are to each other as two to one, and whose lengths coincide with the English standard in *whole numbers*, either feet or inches; in order to simplify the operations depending upon them, and also with a view of establishing the British measures upon a *natural permanent foundation*, which may enable all future generations to obtain similar measures with ease and certainty.

Such are the objects to be obtained by the construction of the apparatus.

According to the doctrine of pendulums, the number of vibrations performed in a given time, are inversely as the square roots of their respective lengths; and yet we find but few instances wherein the lengths of pendulums coinciding with English measure,

sure, whose vibrations in a given time, consist of whole, and divisible numbers; and yet such lengths and vibrations only, will answer the purpose required.

Then since the assumed length of the seconds pendulum in the latitude of London, is 39,2 inches; and according to the result of the following theorem, pendulums which vibrate 42 and 84 times in a minute coincide with English measure, viz:

$$\left. \begin{array}{l} 42^2 : 60^2 :: 39,2 : 80 \\ 84^2 : 60^2 :: 39,2 : 20 \end{array} \right\} \text{Inches.}$$

Such are the lengths and vibrations of the two pendulums applied in the construction of the apparatus, and the difference of their lengths is the measure proposed to be obtained, viz. $80 - 20 = 60$ inches; and this, independent of the mechanical operations requisite to ascertain the center of oscillation, or the true length of pendulums.

The result of this reasoning would have been strictly true, provided the ball were infinitely small, and the assumed length of the second's pendulum were also true, viz $= 39,2$ inches. But since the accu-

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racy

racy of these experiments depends very much on the momentum of the ball overcoming, in some degree, the resistance of the medium, and also the inequalities of the impetus on the pendulum, it becomes requisite to apply such a quantity of matter in the magnitude thereof, as will effectually answer those necessary purposes. Considering likewise, that great advantages may hereafter arise from the magnitude of the pendulum ball corresponding with an aliquot part of the length of each pendulum; and that a metallick globe, two inches diameter, not only coincides with an aliquot part of the length, but may also be considered as containing a sufficient quantity of matter to produce the momentum required for the accuracy of the experiments. Hence a globe according to the above magnitude is particularly chosen for the pendulum ball; for its radius being one inch, or rather $\frac{1}{10}$ of the longer pendulum, and $\frac{1}{20}$ of the shorter, this renders it more capable of being obtained with facility in any future age by approximation, from the mensuration of time alone, than if it consisted of fractional parts of the length thereof.

Such were the motives which induced me to apply a pendulum ball, radius = 1 inch.

Now

Now the radius of the ball being 1 inch, and the distance between the centers of oscillation of the two pendulums and the center of the ball, being in the inverse ratio of their respective lengths, renders the above computation not strictly correct — These are truths well known to mathematicians: but more of this in its due place.

It is likewise equally well known, that the times of vibration are only isochronal whilst the pendulum describes similar arcs. Since their times are directly as $8R + V$, or as 8 times the radius added to the versed sine of the arc described; or as the number 51840 added to the square of the number of degrees contained in the arc: it is therefore evident that pendulums actuated by the force of gravity alone, independent of a maintaining power, whose arcs of vibration gradually diminish till they come to rest, cannot be adjusted with the same degree of accuracy as those which describe equal arcs for the space of several weeks, months, or years.

Whence it appears that the application of a maintaining power becomes absolutely necessary, to com-

penfate for the refiftance of the medium, and which may neither accelerate nor retard the vibrations ; but the poffibility of fuch an application as will effectually anfwer thofe important purpofes, has been much doubted ; therefore, as fuch opinions, however erroneous, may poffibly prejudice the minds of many againft the accuracy of fuch experiments, and as the propofition afferted is rather to be demonftrated by experiment than by reafon ; provifion is made in the conftruction of the apparatus, whereby the truth or fallacy of fuch conjectures may be truly afcertained.

And in order to fhew whether the plan adopted is capable of being reduced to general practice, the movement or maintaining power is not made effentially different from that of a common eight-day clock, nor is it executed with more than common care ; prefuming that if the refult of the experiments depended upon too much accuracy in the executive part of the apparatus, the plan would be the lefs generally ufe-ful.

Therefore the train confifts of the ufual number of wheels and pinions, containing the ufual number of teeth, the firft pinion excepted, being No. 12, as a means of rendering the impetus on the pendulum ra-

ther more equable, and the pendulum wheel No. 21, in conformity to the vibrations of the pendulums.

The dead scapement is applied, with the addition of a counterpoise to the pallets, in order to adjust their center of gravity, and render their vibrations coincident with those of each pendulum, viz. 42 and 84 in a minute, and this in order to remove their supposed tendency to accelerate or retard the vibrations of the pendulum.

The pendulum is thus constructed: it consists of a *solid, spherical, leaden ball*, two inches diameter, its weight 25 oz. 10 dwt. 11 gr. or 12251 grains troy weight, suspended by a *flat steel wire, tempered*, 80 inches of which is nearly equal to 3 grains.

Such is the construction of the pendulum; and it has already been observed that the magnitude of the ball is particularly chosen as being an aliquot part of the length of each pendulum, and more easily obtainable by approximation from the mensuration of time, and therefore it becomes more immediately instrumental in perpetuating the existence of the measures thus derived; for although a little variation in the magnitude

tude.

tude of the ball will only produce an insensible error in the length of the standard measure, yet it nevertheless becomes desirable to proceed by similar means to obtain similar results; therefore it is an object of some importance to apply the above radius, viz. $\frac{1}{80}$ of the longer pendulum, and $\frac{1}{16}$ of the shorter, as the only means of perpetuating the existence of the same measure to the end of time.

It has been objected by some that the quantity of cohesion contained in so small a quantity of matter as that of three grains in a wire = 80 inches, is not capable of sustaining the weight of the ball without stretching, but if an equal mensuration of time, for the space of several months or years, is any proof to the contrary, such testimony is not wanting.

Having premised the general plan of the apparatus, it now remains to give a particular description of its construction.

SEC-

SECTION II.

Of the Construction of the Apparatus.

LET *a a a a b b* plate I, fig. 1, represent a wooden frame, made of two-inch deal plank, strait grained, according to the scale annexed. Deal is particularly chosen in preference to many other substances as being less liable to expand and contract length way of the grain than the generality of timber.

The strength of the frame is intended to give greater stability to the vibrations, and render the result of the experiments more certain. *p h* represents a brass ruler about five feet two inches long, and $\frac{1}{4}$ of an inch thick, let into the plank, till its upper surface coincides with the plane thereof. Its lower end is permanently fixed by a screw at *p*, its upper end is also fixed by a screw at *h*, but with full liberty of expand-

expanding or contracting according to the temperature of the seasons.

Fig. 2, represents the same frame with a part of the apparatus annexed. A a strong brass plate, to which the movement or maintaining power is connected by means of four pillars or dial feet. To the same plate the moveable point of suspension m is permanently fixed, between the chops of which the pendulum wire passes, and in which it is fixed at pleasure by means of a screw compressing them together. To the same plate is also fixed a scale of degrees to measure the arcs of vibration. T the situation of the cord barrel ; H the pulley over which the line passes to suspend the weight or power W ; p h the brass rule before described. But the parts are so much reduced to shew their several relations or situations upon the frame, that they are thereby rendered too minute to be well defined ; therefore they are represented according to their real magnitudes in the following plate.

Plate II, fig. 2, represents the plate A before described ; N the moveable point of suspension, c c its chops, between the parts of which the pendulum wire passes

passes, and in which it is permanently fixed at pleasure by means of the screw *S*, as it were in the chops of a vice. *D D D D* four pillars or dial feet $\frac{3}{4}$ of an inch long, whereby the movement or maintaining power is connected with, or detached from the pendulum at pleasure. *M M* the scale of degrees, to measure the arcs of vibrations. *R R R* the brass ruler before described, lying under the plate *A*, and also under the apparatus *L*, plate II, fig. 1. By means of this apparatus the long pendulum is adjusted. *B* a brass cylinder through which a steel screw *a a* passes, the end of which rests upon *L*, fig. 1, at *y*. *o o* a part of the cylinder which projects at right-angles from it, and upon which projection the pendulum is suspended when the wire is at liberty in *c c*. Now *o o* being raised or lowered by the steel screw, lengthens or shortens the longer pendulum, by previously opening the chops of the moveable point of suspension: the pendulum wire being fixed in *q q* by means of a pin.

At the upper end of the screw *a a*, a wheel No. 25, is fixed for the nicer adjustment of the pendulum, one tooth being $= \frac{1}{1000}$ of an inch in the length of the pendulum.

The plate A, Fig. 2, is fixed to the frame as before directed. The two pillars being inserted at P P for that purpose; and the apparatus L is immovably fixed to the frame by means of several screws.

L, Fig. 5, represents a transverse section of the plate A, to which the moveable point of suspension N is connected, and in which the pendulum wire is inclosed; whence some idea may be formed of its stability. *d d*, fig. 4, represents the crutch through which the wire passes; *c c* the counterpoise to the pallets; *b* the moveable ball whereby their center of gravity may be adjusted, to render the vibration equal to those of each pendulum, viz. 42 and 84 per minute.

Fig. 3 represents the form of the pillars which are inserted into the plate A, and pass between the planks to connect the apparatus to the frame.

Fig. 6 represents the instrument adapted to draw the two lines on the ruler when the pendulums are adjusted: but more of this hereafter.

Plate III represents not only the dial plate, but also the front plate of the movement frame; the indexes

dexes being fixed on the pivots of the first, and pendulum wheel pinions. *c c* the counterpoise; *b* the moveable ball, applied to adjust the vibrations of the pallets.

The preceding account of the apparatus may serve to convey some idea of its construction, to those who are conversant with the mechanism of clocks or watches; therefore it may be altogether needless to attempt a more explicit description thereof; however it may be necessary to give some account of the mode by which it has been applied.

SECTION III.

Concerning the Application of the Apparatus.

1. IT may not be improper to observe, that it was found convenient to fix the apparatus in a diagonal direction in the corner of a room, so far detached from the walls as to allow sufficient room for one's hand to pass behind the frame, to fix or detach the apparatus as occasion may require.

2. The frame being connected to the walls at the upper and lower ends, renders it sufficiently permanent. The brass ruler *R R R* being fixed as before directed, and also the adjusting apparatus *L*, fig. 1, plate II. together with the plate *A*, fig. 2, let the pendulum be suspended upon *o o*, fig. 1, its wire passing through the chops of the moveable point of suspension *c c*.

3. As preparative to the mensuration of time, rest the pallets upon a proper fulcrum, and adjust their

vibrations to coincide with those of the pendulums, viz. 42 and 84 times in a minute, by means of the ball *b*, and make such marks on the arm of the lever *c c*, as the ball may be returned to the same place hereafter.

4. The vibrations of the pallets being thus adjusted, set the ball *b* to perform 42 vibrations in a minute, and having applied the maintaining power to the pendulum, proceed to experiment.

5. The pendulum being then adjusted to perform 42 vibrations per minute, or 60480 times in the space of 24 hours mean time, and this under a temperature 60° on Fahrenheit's scale.

6. The apparatus being thus prepared, let a line be drawn upon the brass ruler *R R R*, along the edge of the plate *A*, fig. 2, plate II, at *Y*, with the instrument *A*, fig. 6, the open end *S* passing underneath the head of the screw *S*, plate III; and the other end bearing upon the plate *A*, at *Y*, plate II. By this means it is presumed that no error can arise by drawing the lines, as might have been the case, from the hand alone.

7. Note

7. Note the quantity of the arc described by the pendulum, viz. $3^{\circ} 20'$, disengage the wire in c c, and detach the maintaining power from the frame, and slide it down to rest upon the point of the screw o, plate I, fig. 1. The apparatus being refixed to the frame, and also the wire in the moveable point of suspension, proceed to the second adjustment of the pendulum, by means of the screw o, plate I, fig. 1, having previously removed the ball b, to vibrate 84 times per minute.

8. The movement being thus prepared for a second experiment, let the pendulum be adjusted to perform 84 vibrations per minute, or 120960 in the space of 24 hours mean time, and draw another line upon the ruler as before directed, and note the arc of vibration, viz. $3^{\circ} : 20'$; it being requisite that the arcs of vibration should be similar to the former, and performed in the same temperature of air.

Thus measures of length, nearly equal to five feet English measure, may be obtained from the mensuration of time, with much more accuracy than has generally been imagined; and this independent of the
me-

mechanical operations requisite to ascertain the center of oscillation, or the true length of pendulums.

The measure or space between the two marks thus obtained, is not 60 inches, according to the result of the preceding problem, but 59,892 inches, according to Mr. Troughton's standard, which seems to indicate that the pendulums were not accelerated by the maintaining power, as is generally supposed; since the lengths of the pendulums must have been increased to compensate for that effect in the measurement of time. However that may be, such is the result of the experiments; whence it appears that the length of the pendulum vibrating seconds of time in the latitude of London, has been computed and found = 39,1196 inches, and not 39,2 inches, as commonly supposed.

According to the above datum, or length of the second's pendulum, viz. 39,1196 inches, it appears that heavy bodies descend through the space of 16,087 feet in one second of time, which is near 16 feet and one inch; therefore since the result of the preceding experiments so nearly coincide with the laws of motion, may we not thence infer that the maintain-
ing

ing power has no improper effect on the vibrations of the pendulums; but only compensates for the resistance of the medium, and neither accelerates nor retards the vibrations? However, such are the effects produced, and therefore I have not the least reason to doubt but that future experiments will abundantly confirm the truth of the former, and fully persuade mankind that invariable measures may be obtained from the measurement of time, under similar circumstances of latitude, elevation, temperature, &c.; and that by the same means the force of gravity, or the true length of a pendulum vibrating seconds of time, may be ascertained with a considerable degree of precision in all latitudes.

Having previously observed that the two pendulums described similar arcs, viz. $3^{\circ} : 20'$ nearly, it may not be improper to take notice, that in order to produce those effects, the apparatus requires powers proportional to the respective lengths of each pendulum, viz. the 80-inch pendulum a power = 32 ounces troy weight; and that of 20 inches, a power = 8 ounces.

SECTION IV.

Of Measures of Capacity and Measures of Weight.

HAVING premised the construction and the application of the apparatus, and compared the result of the preceding experiments with the English standard, we have now to consider the most effectual mode of obtaining measures of capacity and measures of weight, from the space obtained from the mensuration of time, and this with a view of rendering their several relations subservient to each other, at any future period of time, if occasion should require.

It has already been observed that the measure or space obtained from the mensuration of time is 59,892 inches English measure; which we purpose dividing into five equal parts, and each of those parts into ten.

F

And

And as the measure thus graduated is derived from the laws of nature, it may not be improperly distinguished by the appellation of *a philosophical measure*, in contradistinction to all other measures now existing.

The division of the foot into decimal parts, is not altogether adopted to facilitate the business of arithmetical computation, but rather in consequence of the number 10 being the cube root of 1000. For since a cubic foot of rain or distilled water is 1000 ounces, avoirdupois weight, 1 cubic inch of the above measure will = 1 ounce.

Hence it is proposed to obtain original standards for weights nearly corresponding with the English avoirdupois weight; and, as such, may be considered as a permanent basis to found the latter upon: by which means the relation between those of length, capacity, and weight, may be effectually preserved; inasmuch, that the former might be derived from the latter, if occasion so required.

In order to obtain measures of weight from those of length, let us suppose a cubic vessel accurately

rately constructed from the above measure, to consist of any number of cubic inches, which are divisible to unity, and let the weight of the water contained therein be taken for an original standard weight.

Now, since the weight of one cubic foot of *rain*, or *distilled* water, is 1000 ounces avoirdupois weight, one cubic inch of philosophical measure becomes equal to one ounce: therefore if a cubic vessel is constructed to contain 64, or 512 cubic inches, the contents of the former becomes = 64, and the latter = 512 ounces: these numbers being divisible to unity, either of them may be taken for an original standard weight, capable of being subdivided by means of a good balance, or multiplied to any greater extent: but let it be remembered that the accuracy of these experiments, like the former, depend on the same temperature, viz. 60°.

Such are the modes proposed for obtaining measures of length, capacity, and weight, from the mensuration of time: therefore, since all the operations depend on the application of whole numbers, they are thereby rendered more simple, and less liable to

error than if they depended in any degree on fractional parts. And being thus derived, their analogy, or relation to each other, becomes the more obvious.

Now, since it appears that avoirdupois weight may be thus established upon a permanent, unalterable foundation, may it not with propriety be adopted as an invariable standard for troy weight? For, having once truly compared the weights of these different denominations together, and ascertained their relative proportions, viz. the number of grains troy contained in ten, twenty, or any other number of ounces avoirdupois, the latter becomes thereby an invariable standard for the former.

Having premised these matters we have now to consider the construction of a cubic vessel, as an original standard for weights.

It has already been observed, that the contents of a vessel = 64, or 512 cubic inches, may be conveniently adopted for that purpose, as being divisible to unity; but whether the former or the latter will admit of the greatest degree of accuracy in the executive

ecutive part, I leave to the decision of the artist who may undertake the construction of it. However it may not be improper to add, that since the superficial contents of the larger vessel is to that of the smaller as 4 to 1, while their solid contents are as 8 to 1; the former may possibly admit of more accuracy in the executive part than the latter.

In order to avoid any error that might arise from the inaccuracy of filling an open vessel with water, it is proposed to construct a cubic vessel consisting of six complete sides, and to perforate one of its corners for the admission of a funnel, and also to fix the vessel in a diagonal direction to the horizon. In this position the vessel will receive its water, so as to expel the contained air. The weight of the vessel having been previously ascertained, the additional weight arising from the water contained therein, when completely full, becomes an original, invariable standard for avoirdupois weight; obtainable in all future ages, under similar circumstances of temperature, &c., to the end of time: for it is reasonable to suppose, that, from similar causes, similar effects will arise.

But, however that may be in reality, such are the
ideas

ideas which have hitherto occurred on that subject relative to the original construction of measures, both of length, capacity, and weight: for since it appears, from fundry experiments, that an alteration $= \frac{1}{1000}$ of an inch in the pendulum whose length is 80 inches, will produce a sensible alteration in its mensuration of time; may we not thence infer, that the result of such experiments, with the aid of a transit-instrument, must be attended with a considerable degree of accuracy? for since the measures of capacity and weight deduced from thence, depend altogether upon whole numbers, it is reasonable to expect that a considerable analogy in the accuracy of their construction may ensue.

The most useful and most advantageous application of weights and measures being a subject universally known, with regard to their several divisions and combinations, it seems altogether needless to suggest a single idea on that head. I shall therefore proceed to give some account of fundry experiments which have been made to ascertain the effects produced by the maintaining power on the vibrations of the pendulum.

SECTION V.

Of sundry Experiments tending to ascertain the Effects produced on the Vibration of the Pendulum by the maintaining Power.

PROVISION having been made in the construction of the apparatus, with a view of ascertaining the influence of the maintaining power on the vibrations of the pendulum, the following experiments have been repeatedly made with similar results :

I. It may be necessary to observe that the apparatus is purposely constructed to detach the maintaining power from the pendulum without interfering in any degree with the vibrations.

II. When the pendulum has been perfectly adjusted to perform 42 vibrations per minute, and has been going at that rate for the space of several days or
I
weeks,

weeks, and at the same time describing an arc of $3^{\circ}:20'$, nearly.

Under those circumstances the maintaining power has been detached from the pendulum, and its vibrations have been carefully observed and compared by those of a pendulum vibrating seconds, by which the former was adjusted — And the following effects were produced, viz.; in the space of 62 minutes the arc of vibration diminished from $3^{\circ}:20'$, to $1^{\circ}:40'$; and the time gained from the diminution of the arcs, nearly half one vibration.

Such having been the result of several experiments, render the effects produced on the pendulum subject to computation, according to the rules laid down page 5: whence it appears, that the maintaining power only compensates for the resistance of the medium, and neither accelerates nor retards the vibrations, though a contrary opinion has generally prevailed.

And as some farther testimony of the efficacy accompanying the urging or maintaining power, an ingenious Mathematician* has favoured me with the

* John Rotheram, M. D.

following problem computed from the description of the apparatus, and the result of several experiments made therewith. The problem having been examined and approved by Charles Hutton, LL. D. professor of mathematics in the Royal Academy of Woolwich, I presume it may be acceptable to many mathematical readers.

P R O B L E M.

“ THE measure is the difference of the lengths
 “ of two pendulums whose times of vibration are
 “ known to be 84 and 42 in a minute : from this
 “ datum the accurate length of a seconds pendulum
 “ may be obtained. For let y = the length of the
 “ shorter pendulum, viz. the distance between the
 “ point of suspension and the center of the ball.
 “ Then $y + d$ = the distance between the point of
 “ suspension and the center of the ball of the longer
 “ pendulum ; d being = the distance between the
 “ two points of suspension = 59,892 inches.

G

“ Now

“ Now the radius of the ball being one inch, and
 “ the weight of the rod, or the suspension wire, be-
 “ ing almost infinitely small in proportion to the
 “ weight of the ball, by the description of the appa-
 “ ratus; the distance between the center of the ball
 “ of the shorter pendulum and its center of oscilla-
 “ tion will be expressed by $\frac{2}{5y}$. Vid. Emmerfon’s
 “ Fluxions, § 2. prob. 18. exampl. 16.; so that the
 “ true length of the shorter pendulum, viz. the dis-
 “ tance of the point of suspension from the center
 “ of oscillation, will be $y + \frac{2}{5y}$. And by the same
 “ reasoning the true length of the longer pendulum
 “ will be $y + d + \frac{2}{5y + 5d}$. But by mechanics, the
 “ lengths of pendulums are as the squares of the
 “ times of vibrations, and in this case the time of
 “ one vibration is twice that of the other: therefore
 “ $y + \frac{2}{5y} : y + d + \frac{2}{5y + 5d} :: 1^2 : 2^2$; from whence
 “ this equation, $4y + \frac{8}{5y} = y + d + \frac{2}{5y + 5d}$, which
 “ gives, after proper reductions, $y = 19,939$ inches
 “ the length of a pendulum to beat 84 times in a
 “ minute; then to find the length of a pendulum to
 “ beat seconds,

“ $60^2 : 84^2 :: 19,959 : 39,1196$ inches the
 “ length of the seconds pendulum.

“ From

“ From whence we obtain the space heavy bodies
 “ descend through in a second : for by mechanics,
 “ the time of one vibration : the time of a body’s
 “ fall through $\frac{1}{2}$ the length of the pendulum ::
 “ the circumference of a circle : the diameter, viz.
 “ :: 3,1415, &c. : 1 ; and the spaces are as the
 “ squares of the times : therefore $1^2 : 3,1415 \text{ \&c. }^2 ::$
 “ $\frac{39,1196}{2} : 193,047 \text{ inches} = 16,087 \text{ feet, or } 16$
 “ feet and an inch very nearly.”

Therefore since the result of this reasoning so
 nearly coincides with the laws of motion, with respect
 to the space heavy bodies fall through in one second
 of time, may we not thence infer, that a considera-
 ble degree of accuracy may be obtained from the plan
 adopted? infomuch as to presume that future experi-
 ments may establish this business upon a permanent
 foundation—But however that may be, I have the
 satisfaction to lay before the public a faithful account
 of the progress I have made in this necessary work,
 though conscious much more remains to be done
 than either my abilities or leisure will permit.

The following tables are only inserted to shew, in
 some degree, the present state of weights and mea-

tures, established in many parts of Europe; whence some idea may be formed relative to the great embarrassments daily arising from the diversity and incoherence of them in matters of science and commerce.

P. S. Omitted in page 23, to mention, that original standard weights may also be obtained hydrostatically, by immersing a metallic cube, constructed according to the preceding dimensions, in water, temperature = 60° .

A TABLE of foreign Measures carefully compared with the English; shewing the great diversity of their Lengths, and the Number of Parts into which each Foot, Ell, &c., is divided.

Suppose the English foot divided into 1000 equal parts, those here mentioned are in proportion to it, as follows:

Places.	Foot compared.	Length of Feet in English Inches and Tenths.
London - - - -	1000	12, 0
Paris, Royal - - -	1068	2, 8
Amsterdam - - - -	942	11, 3
Brill - - - - -	1103	13, 2
Antwerp - - - - -	946	11, 3
Dort - - - - -	1184	14, 2
Rynland or Leyden -	1033	12, 4
Lorain - - - - -	958	11, 4
Mecklin - - - - -	919	11, 0
Middleburg - - - -	991	11, 9
Straßbourg - - - -	920	11, 0
Bremin - - - - -	964	11, 6
Cologn - - - - -	954	11, 4
Frankfort ad Manum -	948	11, 4
Spanish - - - - -	1001	12, 0
Toledo - - - - -	899	10, 7
Roman - - - - -	967	11, 6

Places.	Proportion of Foot.	Length of Feet in English Inches and Tenths.
Bononia - - - -	1204	12, 4
Mantua - - - -	1569	18, 8
Venice - - - -	1162	13, 9
Dantzick - - - -	944	11, 3
Copenhagen - - - -	965	11, 6
Prague - - - -	1026	12, 3
Riga - - - -	1831	21, 9
Turin - - - -	1062	12, 7
The Greek - - - -	1007	12, 1
Old Roman - - - -	970	11, 6
Bononian - - - -	1140	13, 7
Places.	Ell.	Ft. Inc.
Lyons - - - -	3976	3 11, 7
Boulogne - - - -	2056	2 0, 8
Amsterdam - - - -	2269	2 3, 2
Antwerp - - - -	2273	2 0, 2
Rynland or Leyden - -	2260	2 3, 1
Frankfort - - - -	1826	1 9, 9
Hamburgh - - - -	1905	1 10, 8
Leipsick - - - -	2260	2 3, 1
Lubeck - - - -	1908	1 9, 8
Nuremburg - - - -	2227	2 3, 3
Bavaria - - - -	954	0 11, 4
Vienna - - - -	1053	1 0, 6
Bononia - - - -	2147	2 1, 7
Dunkirk - - - -	1903	1 0, 8
Florence - - - -	1913	1 11, 0

A TABLE of the foreign Weights compared with the English Pound Avoirdupois, divided into 100 equal Parts.

Places.	Pound.
London - - - - -	100
Paris - - - - -	93
Lyons - - - - -	109
Boulogne - - - - -	89
Amsterdam - - - - -	93
Antwerp - - - - -	98
Leyden - - - - -	96
Lorrain - - - - -	98
Mecklin - - - - -	98
Middleburg - - - - -	98
Straßbourg - - - - -	93
Bremen - - - - -	94
Cologn - - - - -	97
Frankfort - - - - -	93
Hamburgh - - - - -	95
Leipfick - - - - -	115
Nuremburg - - - - -	94
Vienna - - - - -	83
Castile - - - - -	99
Lisbon - - - - -	106
Gibraltar - - - - -	103
Toledo - - - - -	100
Rome - - - - -	123
Bononia - - - - -	127

Florence

Places.	Pound.
Florence - - - - -	123
Naples - - - - -	143
Genoa - - - - -	142
Mantua - - - - -	143
Milan - - - - -	140
Parma - - - - -	143
Venice - - - - -	153
Dantzick - - - - -	119
Copenhagen - - - - -	94
Prague - - - - -	106
Cairo - - - - -	161
Constantinople - - - - -	86
See Harris's Lexicon Technicum.	

The instances above recited, evidently shew that similar measures of length, capacity, and weight, must necessarily contribute to the mutual benefit of all nations.

T H E E N D.

E R R A T A.

Page 3, Line 9, for refer, read refer.
6, 12, for i, read is.
8, 7, for existance, read existence.
9, 7, for substances, read substance.
23, 4, for contents, read content.

Fig. 1.

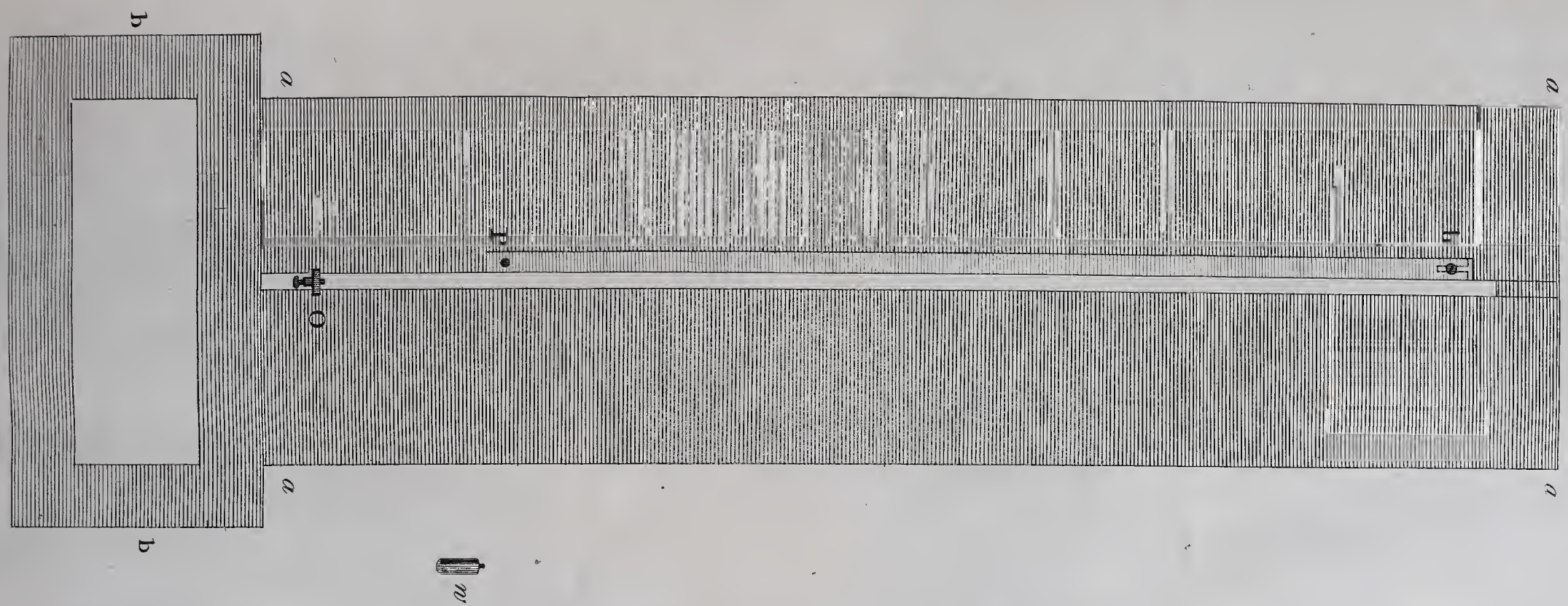
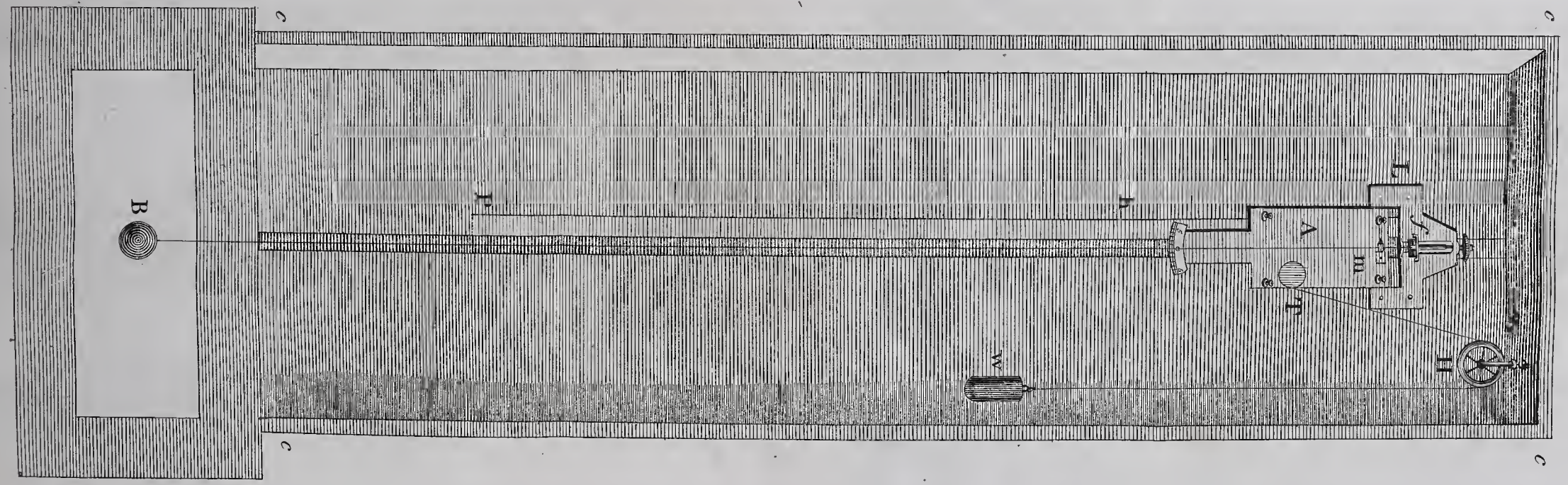


Fig. 2.

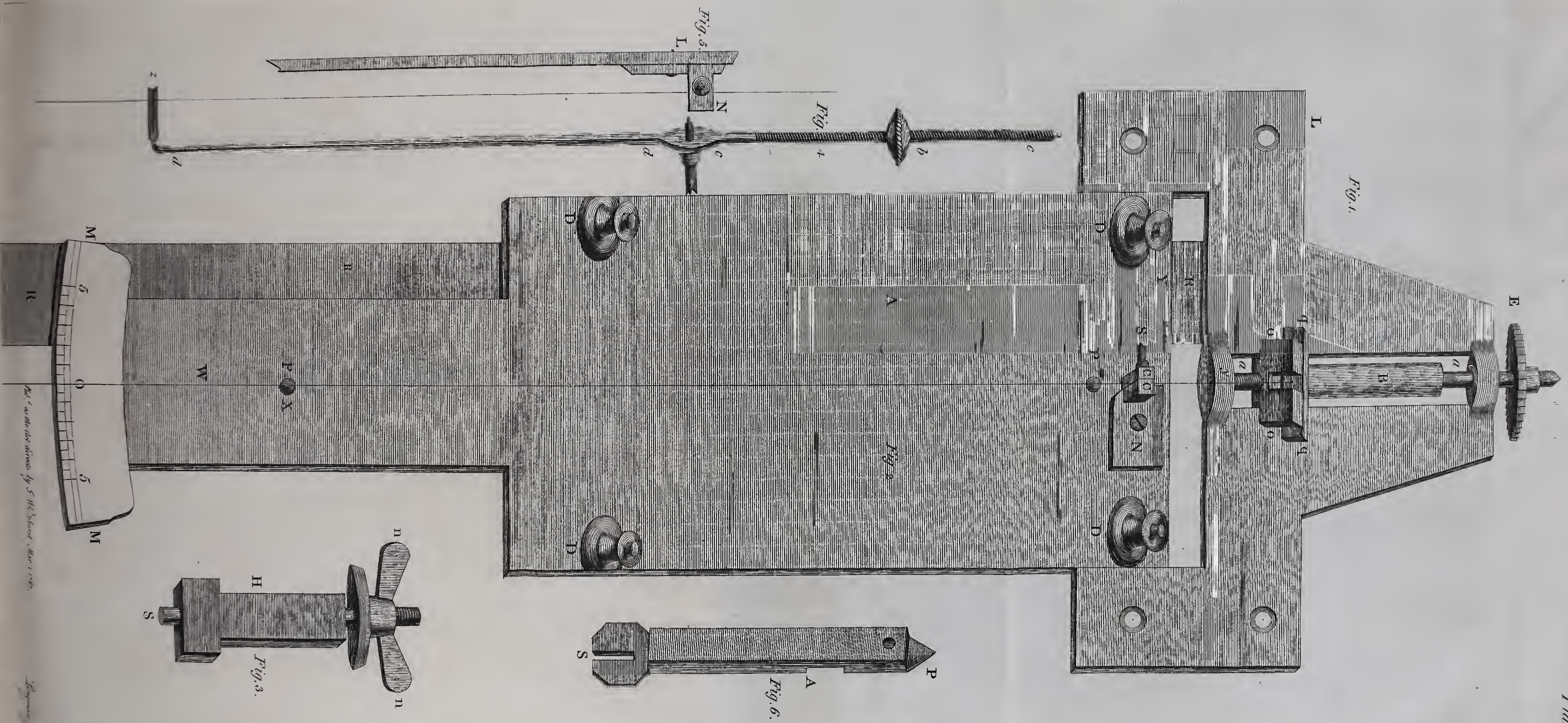


Feet



Pat'd in the U.S. Nov. 17, 1875.

Wm. H. Johnson



Plat. 1 on the last November by S. M. 2nd. - Nov. 1 1888.

Temperature

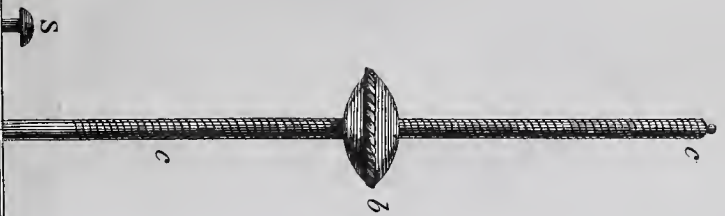
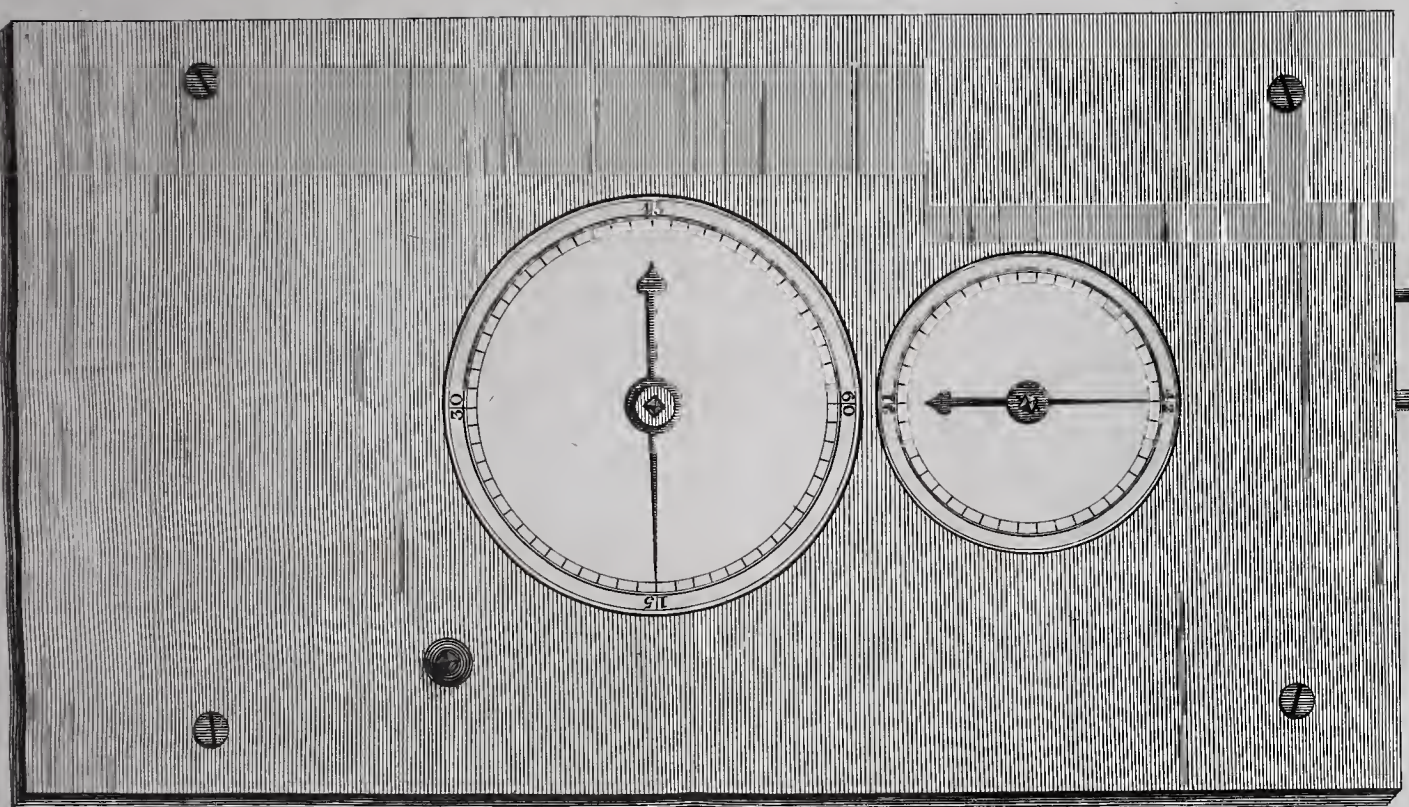


Fig. 1.



Pub. 2nd ed. the last revised by J. W. Richards, March 1, 1907.

Engraved from

A P P E N D I X

T O

M_R. WHITEHURST'S ATTEMPT

TOWARD OBTAINING AN

INVARIABLE MEASURE.

BY THE EDITOR.

A P P E N D I X

TO

MR. WHITEHURST'S ATTEMPT.

BY THE EDITOR.

SINCE the first publishing of Mr. Whitehurst's Attempt to obtain an Invariable Measure, several other ingenious and learned gentlemen have also turned their attention to the same subject, both in this country, and in several other nations of the world; and from their united endeavours, there are now serious expectations that some effectual and beneficial changes will be made in this subject, viz. the regulation of the weights and measures of different countries; toward which the curious experiment of our author, herein described, will doubtless not a little contribute.

The great and leading fact determined by him is this: That in the latitude of London, the difference of the lengths of two pendulum rods is 59.892 English inches, when the one of those pendulums vibrates 84 times in a minute, and the other only 42 times in the minute, each vibrating in an arc of $3^{\circ} 20'$, and in the

H 2

temperature

temperature of 60° of Fahrenheit's thermometer: the pendulum being formed of a perfect ball or globe of lead, of exactly two inches in diameter, weighing 25 ounces, 10 pennyweights, 11 grains, or 12251 grains troy, and suspended by a fine flat, tempered, steel wire, of which 80 inches weighs but three grains.

From this fact many important conclusions may be drawn; as the true length of the seconds pendulum, for any latitude, vibrating in a given arc; the length of the same to vibrate in a cycloid, or an infinitely small circular arc; the descent of gravity, or the space a heavy body will fall in the first second of time; &c.

The calculation above given, in the problem by Dr. Rotheram, this gentleman, it seems, meant only as a rough computation, in which no allowance or correction is made for these following circumstances, viz. the weight of the ball and rod, the resistance of the air, with the effect of the maintaining power, and the magnitude of the arc of vibration. Taking these into the account the same gentleman has since determined (in his Letter to sir John Sinclair, on Weights and Measures, page 18) that the true length of the pendulum vibrating seconds in the latitude of London, in the
temperature

temperature of 60° , is 39.1237 inches. While the authors of the Monthly Review for November 1787, page 383, from the same datum, or leading fact, determine as follows, viz. 1st, that 39.1187 is the length of a seconds pendulum vibrating in a circular arc of $3^{\circ} 20'$; 2d, 39.1362 the length of a seconds pendulum vibrating in a cycloid and in vacuo; 3d, 16.0941 feet is the space fallen through in the first second of a heavy body's descent.

Mr. George Skene Keith too (in his Tracts on Weights, Measures, and Coins) has remarked on Mr. Whitehurst's experiment and conclusions; to whom the editor begs leave to observe, that, from having been a frequent eyewitness of Mr. Whitehurst's experiment, he may depend upon it, that the ball of lead used by him was turned perfectly globular, of exactly two inches diameter, and weight 12251 grains troy, in air, as above-mentioned; from which Mr. Keith can be at no loss for the specific gravity of the metal.

To Mr. Keith it may farther be observed, that Mr. Whitehurst never said or meant that the two pendulums, vibrating 84 and 42 times in a minute, were exactly 20 and 80 inches long, but only nearly so.

Mr.

Mr. Keith adds, "I find that the short pendulum, after making an allowance for the weight of the rod, was (in an arc of $3^{\circ} 20'$) 19.95762816 inches, and the long one 79.83051264 inches, and the difference between the pendulums only 59.87288448 inches, or .01911552 of an inch less than the difference between the rods."

END OF THE APPENDIX.

12
WHITEHURST, J.

O B S E R V A T I O N S
ON THE
V E N T I L A T I O N O F R O O M S;
ON THE
C O N S T R U C T I O N O F C H I M N E Y S;
AND ON
G A R D E N S T O V E S.

O B S E R V A T I O N S
ON THE
V E N T I L A T I O N O F R O O M S;
ON THE
C O N S T R U C T I O N O F C H I M N E Y S;
AND ON
G A R D E N S T O V E S.

PRINCIPALLY COLLECTED FROM PAPERS LEFT

BY THE LATE

J O H N W H I T E H U R S T, F. R. S.

L O N D O N:

PRINTED FOR W. BENT, PATERNOSTER-ROW

1794.

A D V E R T I S E M E N T.

ABOUT ten years ago, the late Mr. John Whitehurst, who died in 1788, had nearly completed for the press, A Treatise on Ventilation, on Chimneys, and the Construction of Garden Stoves ; which was accidentally destroyed *, and never afterward replaced. The papers on which that treatise had been founded, were referred to me for examination some time after his death. They consisted chiefly of remarks, and memorandums relative to the subject, put down without order, or connection. On a careful perusal of them, thinking the observations judicious, and not unworthy of public attention, I endeavoured to arrange them, and to supply several deficiencies. This I was the better enabled to do, from having had frequent opportunities, during a long intimacy with Mr. Whitehurst, of learning his sentiments on the most material points.

For a work thus constructed, it is, however, necessary to request from the Public some degree of indulgence.

* See the Life of Mr. Whitehurst, prefixed to his Works, page 14—15.

It cannot be so perfect and satisfactory as if it had proceeded from the original author of the observations: yet, I hope, in its present form, it will at least be found tolerably clear and connected.

The latest publication on the same subject is by the celebrated Dr. Franklin. His letter to Dr. Ingenhoufz on the Construction and Use of Chimneys* affords many useful hints, but does not, I think, supersede the more enlarged plan of Mr. Whitehurst. Without derogating from the merit of Dr. Franklin's Essay, I may be allowed to observe, that we are in some respect indebted for it to Mr. Whitehurst; the Doctor having been first induced by him to attend to the subject of ventilation and chimneys, while on a visit at Mr. Whitehurst's house in Derby during the summer of the year 1774.

The most defective part of the present work is the last chapter, On Garden Stoves. Having myself paid little attention to their structure and operation, I probably may not have succeeded in doing justice to Mr. Whitehurst's ideas on the subject, more especially as his notes upon it are very short and imperfect. In describ-

* See Philosophical and Miscellaneous Papers, by Benjamin Franklin, LL. D. F. R. S. &c. London 1787.

ing the form of a stove recommended by him, I have also stated the objections made to it by practical gardeners: but even admitting these objections to be just, I could not think it proper wholly to suppress this part of the work, the philosophical observations annexed to the plan being certainly ingenious and well-founded.

JULY 16, 1794.

R. WILLAN.

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